Industrial Engineering and Innovation Management (2023)
Clausius Scientific Press, Canada

DOI: 10.23977/ieim.2023.061014
ISSN 2522-6924 Vol. 6 Num. 10

Research on the transportation and structure optimization of logistics network parcels

Yuliang Dong*

School of Automation, Nanjing University of Science and Technology, Nanjing, 210094, China
**Corresponding author: 15178451464@163.com*

Keywords: ARIMA; Multi-objective Linear Planning; 0/1 Integer Programming

Abstract: The first part of this paper is based on the logistics network line freight data, and the ARIMA time series prediction model is used to predict the cargo transportation situation of each logistics point and the corresponding logistics routes in 2023-01-01 to 2023-01-31. Then, according to the paper requirement, the prediction results of DC14 DC10, DC20 DC35, DC 65 and DC25 at 95% confidence interval. Meanwhile, based on the model one results, this paper gives the residual analysis and the covariance analysis, so as to analyze the robustness of the results. In the second part, due to the closure of DC5 in the logistics site, the cargo quantity of DC5 needs to be allocated. Considering the difference between the access volume and the shipment quantity of DC5 site, this paper analyzes the entry and output respectively. First, based on model 1, the paper predicts the amount of goods to be processed at the DC5 site. Then, based on the constraints, This is transformed into a multi-objective linear planning, and finally based on the model, the DC5 cargo allocation arrangement under the normal operation of the logistics transportation network and the logistics network load are obtained. In this paper, a 0/1 integer planning model is established to deal with the cargo distribution of DC9 shutdown, and introduce decision variables to determine the opening and closing state of a line. Then, based on the model one, the quantity of goods that DC9 site should be processed is predicted, and these goods are allocated to some existing lines and newly opened lines. Meanwhile, in order to save management costs, some lines with low cargo load are shut down, and then the logistics and transportation network is optimized.

1. Introduction

E-commerce logistics network is a system composed of logistics sites and transportation lines, which aims to provide fast and efficient logistics services for e-commerce users. The network usually includes logistics sites such as receiving warehouses, sorting centers and business departments, as well as transportation lines connecting these sites. However, as the order volume of e-commerce users is affected by promotional activities, holidays and other factors, the cargo volume of logistics sites and routes will also fluctuate significantly. In this case, it is very important for managers to predict the cargo quantity changes at each logistics site and line. If changes in cargo volume can be predicted in advance, managers can arrange transportation and sorting plans, thus reducing operating costs and improving operational efficiency. Especially when some logistics sites are temporarily or permanently stopped, based on the forecast results, the processing capacity of each site and the transportation capacity of the line, the designed logistics network adjustment scheme will greatly reduce the impact of the shutdown of the logistics site on the logistics network, and ensure the normal operation of the logistics network. Based on these data, the managers can use the prediction model to predict the future cargo quantity, and formulate the adjustment plan of the logistics network accordingly. This will help to optimize the operation of the logistics network and improve the logistics experience of e-commerce users[1].

2. Model establishment and analysis

2.1 Model 1 analysis

Since in the given table, the cargo quantity changes over time,the paper can predict it using the ARIMA model. This model is a common method for time-series prediction analysis[2]. This paper will analyze and predict the daily shipping changes of each route in the given data and get the final shipping results on January 1 and January 31,2023.In this paper, the paper will separately calculate the prediction results of three routes: DC14 DC10, DC20 DC35, DC 35 and DC25 DC 262, giving their predicted figures and data.

2.2 Model 1 establishment

ARIMA The model has the advantages of simple implementation and small amount of calculation. It is dealing with uneven time series data with large uncertainty, which is suitable for short and medium term prediction. In this paper, the paper will use the data of the 2021-01-01-01 to 2022-12-31 to predict the results of the first month of 2023. The sample is sufficient, the time to predict the future is short, and the accuracy can be guaranteed. In ARIMA (p, d, q), AR is "autoregressive", p is the number of autoregressive items[3]; MA is "sliding average", q is the number of sliding average items, d is the difference times (order) to become a stationary sequence, its model formula can be expressed:

$$\left(1-\sum_{i=1}^{p}\phi_i L^i\right)(1-L)^d X_t=(1+\sum_{i=1}^{q}\theta_i L^i)\varepsilon_t \tag{1}$$

L Is the lag factor,d∈Z,d > 0.

2.3 Model 1 prediction process and results

In this paper, the daily cargo variation data of different routes from January 1, 2021 to December 31,2022 are analyzed as samples, and the ARIMA model is used to obtain our prediction results. In the figure below, the prediction results of DC14 DC10, DC20 DC35, DC25 and DC 25 DC62 5.2 are listed separately. The prediction result of the three routes based on ARIMA model is shown in Fig 1, Fig 2 and Fig 3.

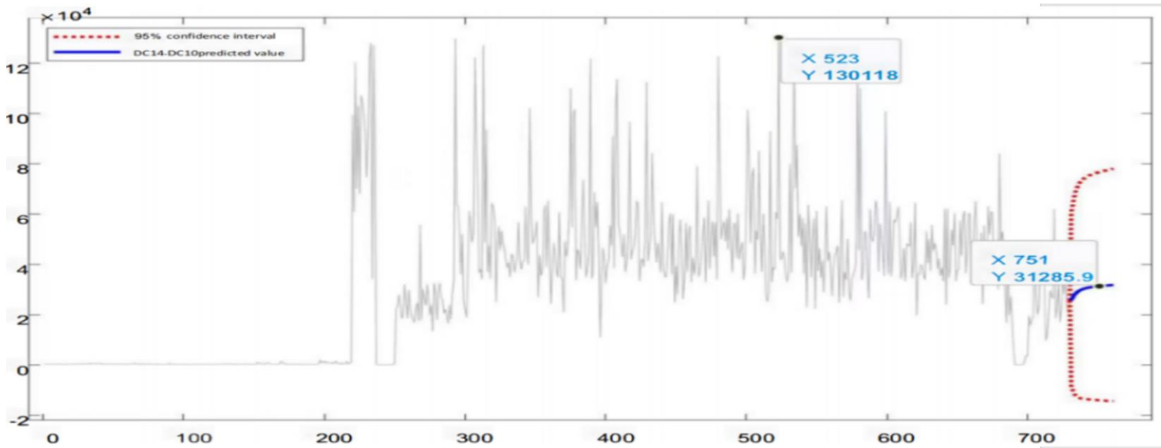

Figure 1: Volume and forecast diagram of DC14 DC10

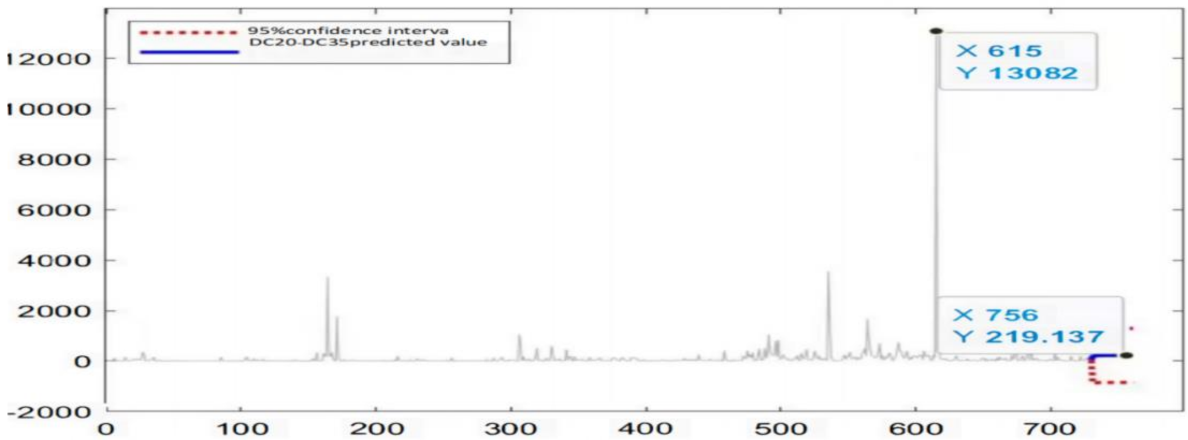

Figure 2: Volume and forecast diagram of DC20 DC35

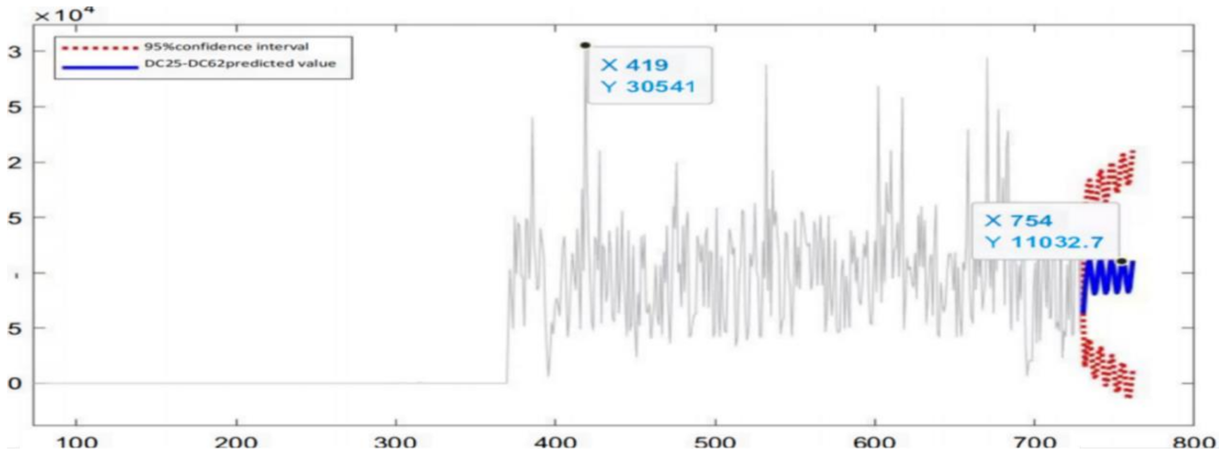

Figure 3: Volume and forecast diagram of DC25 DC62

In the upper figure, the blue line is the prediction result, while the dashed red dashed line is the confidence interval with 95% confidence[4]. Among them, the cargo volume of Route 1 is large, in the order of 104 and gradually rising, which is consistent with the large overall value in history. The cargo volume of Route 2 is small and slowly rises in the range of several hundred, which is consistent with the low reduction of the overall data in the past two years. The data size of Route 3 is about 10,000, and the rise and fall change is obvious, which is consistent with the overall high value and the rise and fall change in the past year. Specific data of the three routes are shown in Table 1:

Table 1: Preast table for three routes

DC14	DC10	25830	DC20	DC35	189	DC25	DC62	8310	2023-01-01
DC14	DC10	28268	DC20	DC35	208	DC25	DC62	11182	2023-01-04
DC14	DC10	28795	DC20	DC35	211	DC25	DC62	10316	2023-01-05
DC14	DC10	29227	DC20	DC35	212	DC25	DC62	8926	2023-01-06
DC14	DC10	29563	DC20	DC35	213	DC25	DC62	8062	2023-01-07
DC14	DC10	30273	DC20	DC35	215	DC25	DC62	10915	2023-01-10
DC14	DC10	30576	DC20	DC35	215	DC25	DC62	10338	2023-01-12
DC14	DC10	30798	DC20	DC35	216	DC25	DC62	8117	2023-01-14
DC14	DC10	30889	DC20	DC35	216	DC25	DC62	8462	2023-01-15
DC14	DC10	30970	DC20	DC35	217	DC25	DC62	9735	2023-01-16
DC14	DC10	31043	DC20	DC35	217	DC25	DC62	10973	2023-01-17
DC14	DC10	31231	DC20	DC35	218	DC25	DC62	8984	2023-01-20

2.4 Model 2 analysis

The paper will get the predicted value of receiving goods and transporting goods when DC5 is not suspended. Due to the shutdown of DC5, the routes to DC5 and from DC5 will be affected, so it is necessary to consider how to use other stations to share the transportation functions undertaken by DC5. Taking the shipment to DC5 as an example, the proportional coefficient of the allocated quantity will be determined according to the historical average of the shipment at each logistics site, and the total intake per day will be allocated. In the same case of shipments from DC5, total shipments are distributed proportionately to all lines shipped from DC5. After distribution, recalcalculate the quantity between the logistics site and the line. At the same time, the upper limit of each logistics site should also be considered. In this paper, an optimization model is needed to optimize the diversion scheme of the line to make all the parcels operate normally. Eventually, the model will be reduced to a simple multi-objective linear planning model, with the goal of ensuring that the affected cargo is as small as possible, the number affected is as small as possible, and the number of days is as small as possible. At the same time, it is also necessary to consider the load capacity of each line. Under the condition of meeting the previous conditions, the ratio of the cargo quantity of the distribution route to the historical maximum of the route and the cargo quantity of the route should be considered, and then the cargo volume of the whole network can be calculated to ensure that the overall network load is as small as possible and the load is average as much as possible.

2.5 Model 2 establishment

Now, from January 1, the DC5 is off service. Considering that the DC5 logistics site needs to accept the inflow of goods, and the quantity of goods that needs to be exported from DC5 needs to be allocated. And these two goods volume the paper need to consider separately, in order to achieve a certain accuracy and rationality. First of all, based on the ARIMA auto-regressive moving average prediction model established , the logistics site related to DC5 is found according to the historical data, and the shutdown of DC5 is predicted within one month, that is, the total amount of goods received within one month, from January 1 to January 31,2023. Next, this paper will calculate the average value of the historical cargo volume at each logistics site when DC5 is the terminal based on historical data. And this average value is the basis for calculating the proportion coefficient of the allocated goods quantity. Scale ate total incoming r ij to all outgoing lines of DC5. Similarly, the total shipment of DC5 vij is assigned to all incoming lines of DC5. Recalculate the quantity between the logistics site and the line after allocation. At the same time, it is necessary to take into account the various constraints in the topic, mainly the upper limit of each logistics site, so the paper can treat as a multi-constraint linear planning, so as to better analyze the impact of DC5 shutdown on the logistics network. The optimization model the paper built should make all parcels flow as normally as possible, while minimizing the number of affected lines and network load. Here nin 5 to describe the number of lines affected because some lines cannot be shipped to DC5, use nout 5 to describe it

Number of lines affected because DC5 cannot be transported to other lines. Obviously, the theoretical minimum of the two quantities is the actual value shipped to DC5 and from DC5. A description method of the load is presented first[5]. According to the solution results of the above model, the freight volume of DC1 to DC81 in each logistics site is calculated, and then the proportion analysis is made with the maximum freight volume max (DCi) that can be handled by the site. As the load degree of the site, zi. The formula is as follows:

$$z_i = \frac{DC_i}{\max(DC_i)} \tag{2}$$

To consider the balance of the load degree, this paper uses the variance to describe whether the overall load is uniform. The formula is as follows:

$$\begin{cases} E(Z_i) = \dfrac{\sum_{i=1}^{n} Z_i}{n} \\ D(Z_i) = \sum_{i=1}^{n} \left(Z_i - E(Z_i)\right)^2 \end{cases} \tag{3}$$

$$\begin{cases} X_{it} + W_{i5} \cdot r_t < Max(X_i) \quad 1 \le t \le 31 \\ H_{jt} + Y_{5j} \cdot v_t < Max(H_j) \quad 1 \le t \le 31 \\ \min X_i + H_j \\ \min n_{in5} + n_{out5} \\ \min D(Z_i) \\ \sum_i W_{i5} = 1 \\ \sum_j Y_{5j} = 1 \end{cases} \tag{4}$$

Further analysis, it is found that due to the limitation of various constraints, some goods existing for several days can not operate normally, that is, it is difficult to find a feasible solution of the above formula. At this point, not only the number of changing routes: the minimum number of days when goods cannot operate normally. On this basis, this paper is established:

$$\begin{cases} X_{it} + W_{i5} \cdot r_t < Max(X_i) \quad 1 \le t \le 31 \\ H_{jt} + Y_{5j} \cdot v_t < Max(H_j) \quad 1 \le t \le 31 \\ \min X_i + H_j \\ \min n_{in5} + n_{out5} \\ \min D(Z_i) \\ \min\left(t_{X_i} \ge Max(X_i) + t_{H_i} \ge Max(H_i)\right) \\ \sum_i W_{i5} = 1 \\ \sum_j Y_{5j} = 1 \end{cases} \tag{5}$$

2.6 Model 2 prediction process and results

This is a typical multi-objective solution. In order to facilitate the operation, the paper need to simplify the multi-objective to a single-objective. Here, the weight method is adopted to analyze. Its core idea is to sum multiple objective functions weighted, and take the new function as the unique objective function to achieve the purpose of simplification. First, it is necessary to clarify the objective functions and constraints of the logistics network input optimization, namely the multiple objective functions to be solved and the constraints, all of which have been given in the previous section. Then, it is weighted and summed with the following formula:

$$F(\mathrm{x}) = \sum_{i=1}^{k} \alpha_i f_i(x) \tag{6}$$

Finally, the logistics network optimization after the shutdown of DC5 is transformed into a single goal planning:

$$\min F(\mathrm{x}) = \sum_{i=1}^{k} \alpha_i f_i(x) \tag{7}$$

In this paper, from the shipment to DC5 and DC5, the goods originally planned to DC5 need to be temporarily transferred to other sites. Bring the prediction results of each route into the previous section (2) as actual data, calculate the route situation when the two target functions are small, and organize them into tables and figures. According to the calculation results and the data in the table, it can be seen that due to the existence of large scale and strong transportation capacity such as DC10, DC14, DC62 and so on stations, the amount of goods transported to DC5 every day can be handled normally. Due to the large data, the route to DC5 is presented in this article.

The maximum value of the load amount is only 70.62%. Except for a few routes, most routes have low load levels, so all shipments to DC5 are considered well handled.

In the Fig 4, the orange route is the variation of the route, the blue line is the total variation of the route, and the value of the gray broken line is the load degree of the line.

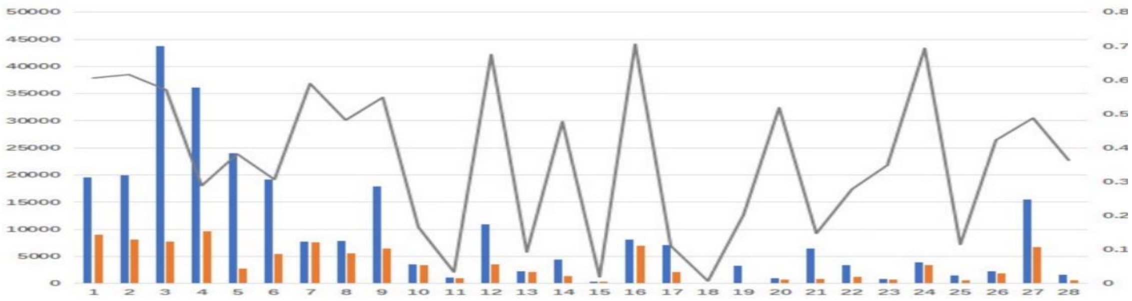

Figure 4: A Schematic diagram of the route changes shipped to DC5 on January 1st

In the same way, the distribution of the goods originally shipped by DC5 on January 1st after processing, as shown in the Table 2:

Table 2: Schematic of route changes shipped by DC5 on January 1

number	The initial route	Change the route	variation	Total amount after change	charge	number	The initial route	Change the route	variation	Total amount after change	charge
1	DC5→DC10	DC14→DC10	2320	32254	64.66%	4	DC5→DC8	DC25→DC8	571	9444	30.51%
2	DC5→DC14	DC15→DC14	1630	6240	41.11%	5	DC5→DC62	DC44→DC62	151	2731	19.58%
3	DC5→DC4	DC22→DC4	636	12856	55.61%						

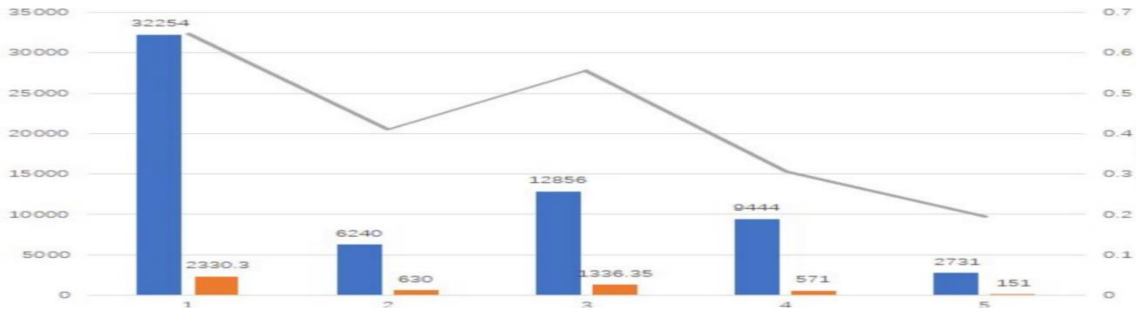

Figure 5: A Schematic diagram of the route changes shipped to DC5 on January 1st

According to the data in the Table 2 and Fig 5, a general conclusion can be made. In order to ensure that the load is as small as possible and the load distribution is as balanced as possible, the route with large transportation volume should be transferred to logistics stations with strong transportation capacity as far as possible, and the route with small transportation capacity should be transferred to logistics stations with weak transportation capacity for transportation. At the same time, in order to keep the affected routes as small as possible, a batch of goods should not be allocated to two or more stations for transportation

3. Model 3 analysis

The forecast value of the goods received and the goods delivered by DC9 is not suspended. Then, considers the method of dynamic adjustment, the paper can freely determine the switch of the logistics line, so more variables need to be considered to decide the opening and closing of the route. This paper considers abstracting as a 0/1 integer programming, with 0 closed and 1 open[6-7]. The rest of it is similar. With as little the number of moving routes (including new routes), the number of goods affected and as few number of days when goods are affected.

3.1 Model 3 establishment

This paper considers the dynamic adjustment of the network structure, that is, the switching status of the logistics line can be adjusted daily, rather than just a one-time cargo allocation before the shutdown of DC9. Therefore, there are more variables to be considered, including deciding whether to switch a logistics line within each day, and the impact of the switching line on the overall network load needs to be considered. In this case, the optimization method based on integer programming can be used[8]. Specifically, can be abstracted into a 0/1 integer programming. In a daily decision, you need to decide the status of each logistics line, turning it on or off. Consider both the maximum transport capacity of the line and the flow of goods between the line and DC9. You can set the state of each line as a 0/1 variable, with 0 off and 1 on. You need to restrain the transport capacity of each line, and the in and out of each line. At the same time, the paper need to consider the balance of network load, that is, to balance the load of each line as far as possible to avoid excessive load of some lines.

Based on the above variables and constraints, an integer programming model can be built. It can be solved using the solver to obtain the optimal decision every day, as well as the corresponding network load and cargo flow. In solving, the paper need to regard each day as a time point, considering the switching status and flow allocation of the day, as well as its impact on the next few days. Given the complex, it may need to perform multiple rounds of solution and gradually optimize the model to obtain more accurate decision results.

$$\begin{cases} \min \sum_{i=1}^{n} \sum_{j=1}^{n} C_{ij} \cdot X_{ij} \\ \min \sum_{i=1}^{n} \sum_{j=1}^{n} \Delta X_{ij} \end{cases} \tag{8}$$

$$C_{ij} \in \{0,1\} \quad i = 1,2 \cdots 81; j = 1,2 \cdots 81 \tag{9}$$

Xij represents each line. As can be seen from the objective function, while ensuring the normal operation of the logistics and transportation network, the number of lines with state change should be minimized, including the opening and closing of the line and the change of cargo volume of the line. [9].Similarly, according to the treatment method, the following constraints should be met, that is, the conditions that should be met after allocating the cargo quantity of DC9 site to other sites. The total cargo volume at each site shall not exceed the maximum transport capacity.

$$\sum_{i=1}^{n} W_{ij} \left(\sum_{i=1}^{n} C_{ij} \cdot X_{ij} \right) \le M_i \quad i = 1,2,3 \cdots 81 \tag{10}$$

Among them, wij is the cargo flow from site i to site j and Mi is the maximum logistics limit of line i; secondly, the cargo flow from DC9 site is allocated to other sites.

$$\sum_{j=1}^{n} W_{9j} X_j = 0 \tag{11}$$

3.2 Model 3 prediction process and results

After the calculation of the model, the chart of the route change to DC9 is given. According to the forecast, the routes to DC9 and DC9 in January are less, so the route change of the routes to DC9 and

DC9 for the whole month is given here. Which lines in the route are original lines and which are new lines will be indicated in the last column of each row in Table 3[10].

Table 3: Schematic chart of route changes shipped to DC9 in January

number	The initial route	Change the route	variation	Total amount after change	charge	remarks	number	The initial route	Change the route	variation	Total amount after change	charge	remarks
1	DC14→DC9	DC14→DC70	473	946	15.12%	original	7	DC14→DC9	DC14→DC18	5661	5661	10.72%	new
2	DC44→DC9	DC44→DC40	900	997	32.58%	original	8	DC26→DC9	DC26→DC18	6561	6561	12.43%	new
3	DC23→DC9	DC23→DC8	456	1355	23.59%	original	9	DC21→DC9	DC21→DC10	1180	27611	31.37%	original
4	DC14→DC9	DC14→DC8	422	4642	14.64%	original	10	DC44→DC9	DC44→DC35	6332	7092	12.20%	original
5	DC36→DC9	DC36→DC35	4526	9087	28.55%	original	11	DC23→DC9	DC23→DC40	1054	2108	16.41%	original
6	DC8→DC9	DC8→DC12	5551	5551	10.52%	new	12	DC27→DC9	DC27→DC70	1178	2176	6.12%	original

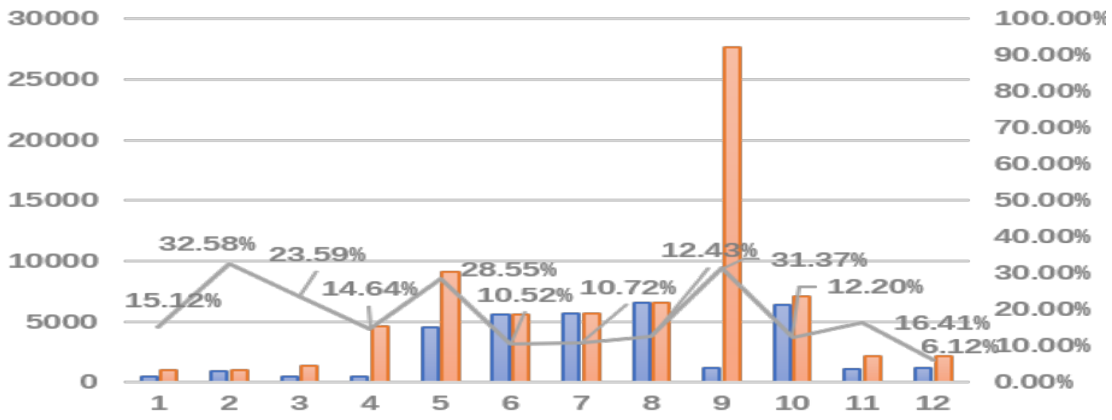

Figure 6: A Schematic diagram of the route changes shipped to DC9 in January

In the Fig 6, the blue line is the variation of the route, the orange line is the total variation of the route, and the value of the gray broken line is the load degree of the line.

Table 4: Schematic chart of route changes shipped to DC9 in January

Number	The initial route	Change the route	variation	Total amount after change	charge	remarks	number	The initial route	Change the route	variation	Total amount after change	charge
1	DC9→DC3	DC18→DC3	8112	22112	42.00%	new	4	DC9→DC14	DC19→DC14	1770	3699	22.01%
2	DC9→DC14	DC29→DC14	10111	23111	55.20%	new	5	DC9→DC12	DC28→DC12	4526	9087	28.55%
3	DC9→DC5	DC10→DC5	4787	8253	37.67%	original	6	DC9→D34	DC8→DC34	1040	1160	10.52%

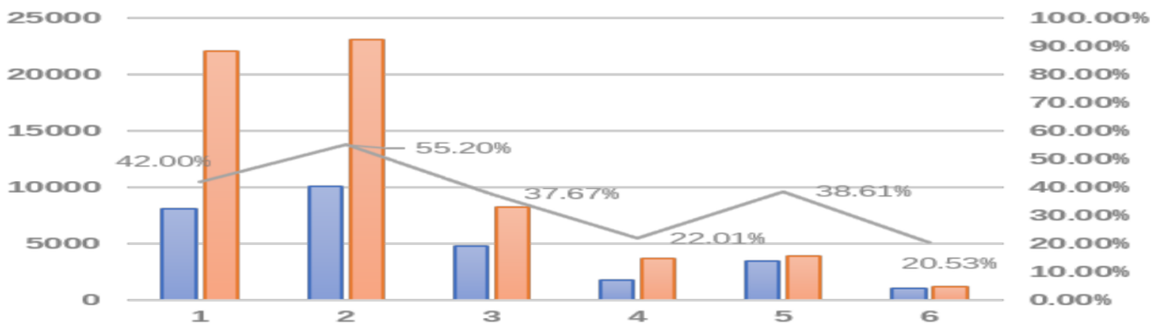

Figure 7: A Schematic diagram of the route changes shipped from DC9 in January

According to the Table 4 and Fig 7, a general rule can be obtained. In the context of this paper, if the amount of goods is relatively small, generally choose the original route in the transport capacity of the same or slightly stronger line to help transport. If the cargo volume is relatively large, if the existing path load is large, the new route can be selected to solve the paper that the original route load is relatively large.

4. Conclusion

The models of the subsequent problems are based on the previous ARIMA model, which has a small amount of calculation and has great advantages in the large time series without smoothness and uncertainty, and the accuracy of its data can be effectively guaranteed. This also lays an important foundation for the subsequent treatment of the linear planning model. The linear planning model considers the limitations of multiple constraints and multiple objective functions, considering more comprehensive factors and high reliability; The degree of network load based on the model is normal, indicating the high validity of the model. At present, this paper still has shortcomings, such as: in the analysis of the impact of the Spring Festival on the logistics network and when solving the results of multi-objective linear planning, the right weight method solves the accuracy and efficiency of the results. In the future, the impact of the Spring Festival holiday should be included in the original logistics and transportation network model and improved in the following aspects: The improvement of transportation volume forecast model: it can focus on the data of logistics and transportation flow during the previous Spring Festival, and predict the volume of logistics network from January 1 to January 31,2023. Adjustment of the transportation capacity of new network lines: Since the load and transportation capacity of the transportation network will be affected during the Spring Festival, the transportation capacity during the Spring Festival transportation period can be considered to better optimize the role of the network and the ability to deal with complex situations. When solving the multi-objective linear programming and integer programming, the genetic algorithm or particle swarm algorithm can be introduced to improve the solution accuracy and efficiency.

References

[1] Zhang Jie. Design and development of the warehouse management system based on AGV [D]. Hubei: Hubei University of Technology, 2022

[2] Geng Luhua. Joint optimization method for transportation logistics scheduling based on path matching [J]. Journal of Shenyang University of Technology, 2023, 45 (02): 200-206.

[3] Zhang Mingxiang. A data processing model for logistics scheduling [D]. Nanjing University of Posts and Telecommunications, 2016

[4] Chen Bo. Study on the site selection path of emergency logistics considering random demand and travel time [D]. Liaoning: Dalian University of Technology, 2022.

[5] Zhang Ningbo. Research on AGV path planning and collaborative scheduling strategy in smart factories [D]. Zhengzhou University of Light Technology, 2022.

[6] Yin Hong. Analysis of the network optimization problem of emergency materials distribution [J]. Science and Technology Wind, 2015, No.272 (14): 10 + 12

[7] Hu Zhichao. Research on Logistics Scheduling based on Machine Learning and heuristic algorithm [D]. Beijing University of Posts and Telecommunications, 2019

[8] Sun Youqiang. Research on the emergency logistics scheduling model in the uncertain traffic state [D]. Taiyuan University of Science and Technology, 2020

[9] Wang C L , Wang Y , Zeng Z Y ,et al.Research on Logistics Distribution Vehicle Scheduling Based on Heuristic Genetic Algorithm[J].Complexity, 2021, 2021(11):1-8.DOI:10.1155/2021/8275714.

[10] Ye Hanglu, He Lili. Intelligent logistics scheduling planning based on the improved ant colony algorithm [J]. Computer system application, 2021, 30 (01): 207-213.